Anesthesia of the Acute Trauma Patient

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Trauma Patient
• Unique challenge to veterinary facility
  • Resource-intensive care
  • Multiple injuries to multiple body systems
  • Acute injuries overlaid and interact with a variety of chronic conditions
• Greater than 10% of caseload in small animal practice
  • Most are automobile related

Trauma Patient
• Types of injuries
  • Vehicle (and other blunt force trauma)
    • Most common
    • High energy impact results in blunt force trauma
    • Infection less likely if addressed quickly
  • Physical abuse
    • Varies in presentation
    • Blunt force, chemical, thermal, and explosive injuries
  • Animal attacks
    • Very problematic
    • Often also involves severe sepsis
    • Deep tissue injuries are often present but may not be initially visible
Outline

- Trauma Pathophysiology
- Shock
- Preoperative evaluation and management
- Fluid therapy
- Preoperative drug selection
- Induction agents
- Maintenance of anesthesia
- Intraoperative monitoring
- Potential intraoperative problems
- Postoperative analgesia

Trauma Pathophysiology

- Physical disruption from high energy impact
- Local biochemical response of injured tissues
- Systemic biochemical response of organ systems

Physical Tissue Disruption

- High Energy Impact
  - Follow a certain pattern of energy transfer
  - Results in a predictable set of tissue injuries
  - Four basic mechanisms of blunt trauma
    - Tension
    - Degloving injury
    - Shear force
    - Long bone fracture
    - Compression
    - Pulmonary and myocardial contusions, hepatic and splenic rupture
    - Overpressure
    - Bladder, intestinal, and body wall rupture
Physical Tissue Disruption

- Dogs versus Cats
  - Dog injuries tend to be from hind end forward
    - Turn away from oncoming vehicle
    - Pelvic and pelvic limb injuries
    - Intrathoracic injuries often secondary from transfer of force
  - Cat injuries tend to be front end/head trauma
    - Turn toward oncoming vehicle
    - Less likely to survive

Local Biochemical Response

- Three Phases
  - Nervous phase
    - Vasconstriction and vasodilation
    - Ischemia and reperfusion injury
    - Endothelial permeability and edema
  - Inflammatory phase
    - Migration of inflammatory cells and platelets
    - Release of pro-inflammatory cytokines
    - Enhanced susceptibility to SIRS and ARDS
  - Endocrine Phase
    - Tissue repair and remodeling
    - Post-traumatic inflammation
    - Angiogenesis and scar tissue formation

Systemic Biochemical Response

- Local reactions can also be applied systemically
  - Shock, redistribution of blood flow, ischemia, reperfusion
  - Massive liberation of inflammatory mediators
  - Catabolism followed by anabolic convalescence

- Extent of systemic reactions has greatest impact of suitability for general anesthesia
  - SIRS, MODS, ARDS
Shock

• A state of generalized inadequate tissue perfusion
  • Recovery is related to magnitude of oxygen debt

• Types of shock seen in trauma patients
  • Septic shock
  • Hemorrhagic shock
  • Spinal shock

Septic Shock

• Develops after a time lapse after injury
• Associated with SIRS
  • Global activation of the immune system with release of cytokines
    • Vascular permeability
    • Neutrophil infiltration
    • Capillary microemboli
    • Poorly regulated coagulation
    • Propagation of inflammatory response
• Chronic impairment of oxygen deliver to tissues leads to irreversible shock (MODS)

Septic Shock

• Clinical signs
  • Early (hyperdynamic phase)
    • Brick-red mucous membranes
    • Tachycardia
    • Normal or low blood pressure
    • Low vascular resistance
  • Late signs
    • Dogs
      • Tachycardia, hyper or hypotension, hyperglycemia
      • Shock Organs: GIT>liver>kidney>lungs
    • Cats
      • Bradycardia, hypotension, hypoglycemia
      • Shock organs: lungs (rapid fluid accumulation)
Hemorrhagic Shock

- Commonly encountered in acutely traumatized patient
- Clinical signs include:
  - Pallor and/or cyanosis
  - Disorientation
  - Tachycardia, dysrhythmias, and pump failure
  - Hypotension, progressive metabolic acidosis
  - Oliguria, DIC
- Compensatory mechanisms will maintain BP until ~40% of blood volume is lost
  - After 40% loss compensation fails and shock becomes irreversible

Spinal Shock

- Common sequela to spinal cord injury or blunt trauma
- Disruption of sympathetic outflow from thoracolumbar trunk
- Clinical signs
  - Warm extremities (peripheral vasodilation)
  - Bradycardia with hypotension
  - Responsive only to inotropic-pressor type drugs
  - Relative hypovolemia (increases vascular capacity)

Anesthetic Considerations

- Primary goal:
  - Optimize tissue perfusion and oxygen delivery to all vital organ systems
  - Induce unconsciousness
  - Provide analgesia and muscle relaxation
General Anesthesia for The Trauma Patient

- Preoperative evaluation and management
- Fluid therapy
- Preoperative drug selection
- Induction agents
- Maintenance of anesthesia
- Intraoperative monitoring
- Potential intraoperative problems
- Postoperative analgesia

Preoperative Evaluation and Management

- As a general rule, anesthesia should not be undertaken until a patient’s vital organ functions have been assessed and stabilized
- Immediate attention to “ABC”s
  - Deemed adequate before proceeding
  - Oxygen supplementation and ventilatory support
  - Poor ventilation or oxygenation
  - Chang in mental status
  - Signs of airway obstruction
- Assess adequacy of intravascular volume and cardiovascular function
  - Compensatory mechanisms can be confounding
  - Vasovagal reflex, increased heart rate, splenic contraction

Preoperative Evaluation and Management

- Base line values
  - TPR, MM and CRT
  - Temperature of extremities, mental status
- Minimum data base
  - PCV, TT, blood glucose, BUN
  - Urine specific gravity
- Thoracic radiographs
  - Pulmonary lesions
    - May not be radiographically apparent for 12 to 24 hours
    - Worsen for 24 to 35 hours
    - Resolve in 2 to 5 days
- ECG
  - Myocardial contusions and VPCs
    - Appear 24 to 72 hours after trauma
Fluid Therapy

- Most animals are hypovolemic
  - Pre-existing fluid deficits, ongoing loss, vasodilation (shock)
  - Anesthetic drugs aggravate hypotension and decrease sympathetic tone
- Crystalloids should be mainstay of therapy
  - Chosen based upon acid-base/electrolyte abnormalities
  - 3ml required to replace 1 ml of blood loss

Fluid Therapy

- Colloid solutions
  - Blood products and synthetic solutions
    - Used in addition to crystalloids
      - Albumin < 1.5 g/dL
      - TP < 3.5-4.0 g/dL
    - 1 ml required to replace 1 ml of blood
  - Hetastarch
    - 10 to 20 ml/kg/day
    - High doses can interfere with coagulation

Fluid Therapy

- Fresh frozen plasma
  - Not effective for volume replacement
  - Use for albumin, coagulation factors, and plasma proteins
  - 6-10 ml/kg
- Whole blood
  - Trauma patients have increased oxygen demand
  - Serial assessment of blood lactate levels
    - Should decrease with therapy
  - Persistent elevations above 8 mM/L despite therapy indicated poor prognosis (90% mortality rates)
  - PCV > 25% ensure adequate oxygen delivery to tissues
**Fluid Therapy**

- **Blood Administration**
  - "Rule of Thumb":
    - 2 ml/kg raises PCV 1% (whole blood)
    - 1 ml/kg raises PCV 1% (packed red cells)
  - Calculation:
    - Amount of Blood Needed = Desired PCV - Patient PCV
    - PCV of Donor Blood x Recipient Blood Volume
    - Recipient Blood Volume:
      - Dog = 50 ml/kg
      - Cat = 70 ml/kg
      - (8% of body weight in kg)
  - Rate of Administration: 0.1 ml/kg for first 30 minutes
  - Then 2 ml/kg/hr until desired PCV is achieved

**Fluid Therapy**

- **Electrolyte abnormalities**
  - Should be normalized before anesthesia
  - Hyperkalemia often seen in trauma patients
    - Renal compromise, urinary obstruction or rupture, massive tissue trauma, dehydration, acidosis
    - >6.0 mEq/L should not be anesthetized
    - >5.5 mEq/L, should not be anesthetized unless an emergency
    - Automaticity, conductivity, contractility, and excitability of the myocardium are depressed
    - ECG
      - Tall T waves, Prolonged PR interval, Wide QRS, Loss of P wave
  - Treatment
    - 0.9% sodium chloride
    - Glucose (insulin)
    - Sodium bicarbonate
    - Calcium

**Preoperative Drug Selection**

- Choice of agents chosen based on:
  - Current physical status, history
  - Reason for presentation, procedure
  - Special attention should be paid to cardiovascular and respiratory effect of agents
  - Preoperative sedation may be unnecessary is patient is compromised or depressed
  - Do not withhold analgesic medication
Opioids

- Have favorable cardiovascular profile
- Cardiovascular function is maintained
- Can act as a respiratory depressant
- Sedative in compromised patients
- Provide pre and post operative analgesia
- Have anesthetic sparing effects
- Choices:
  - Morphine – 0.5-1.0 mg/kg IV, IM
  - Hydromorphone – 0.1-0.2 mg/kg IV, IM
  - Methadone – 0.25-0.5 mg/kg IV, IM
  - Fentanyl – 5-20 µg/kg IV
  - Buprenorphine – 5-20 µg/kg IV, IM
  - Butorphanol – 0.2-0.4 mg/kg IV, IM

Benzodiazepines

- Mild tranquilizers and muscle relaxants
- Minimal cardiovascular or pulmonary depression
- Commonly given in combination with other drugs
  - Opioid
  - Ketamine
  - Diazepam (0.1-0.4 mg/kg, IV)
  - Propylene glycol base
  - Midazolam (0.1-0.4 mg/kg, IM, IV)

Agents to Avoid

- Ketamine
  - Stimulate endogenous release of catecholamines
  - Myocardial depressant
  - Arrhythmias, increased intracranial pressure
  - Use with caution
    - Reduce dosage
    - Low dose CR for pain management
- Ace promazine
  - Peripheral vasodilation
  - Prolonged bleeding, anemia
- Dexmedetomidine
  - Profound changes in cardiovascular function
Induction Agents

- As with premedications, selection should be based on condition of patient

Opioids

- Can be used as induction agents
- Left ventricular function, cardiac output, and systemic blood pressure are well maintained
- Usually used in combination with opioid
- Fentanyl 10-20 μg/kg IV
  - Administer midazolam (0.2 mg/kg) IV prior
  - Can cause profound bradycardia
  - ECG at induction
  - Anticholinergic responsive
  - May require mechanical ventilation

Propofol

- Also useful for rapid sequence inductions
- Similar side effects as thiopental
  - Peripheral vasodilation may be greater than barbiturates
  - Extrahepatic sites of clearance make it useful in patients with liver disease
- Fentanyl/Propofol inductions
  - Fentanyl 5-10 μg/kg IV
  - Propofol 0.5-2 mg/kg IV
- Lidocaine/Propofol inductions
  - Lidocaine 1-2 mg/kg IV
  - Propofol 1-4 mg/kg IV
- Midazolam/Propofol inductions
  - Midazolam 0.2-0.4 mg/kg IV
  - Propofol 1-4 mg/kg IV
Etomidate

- Ultrashort acting induction agent
- Useful in patients with cardiovascular instability
  - Minimal effects on heart rate, rhythm, cardiac output, and systemic blood pressure
  - Minimal respiratory depression
- Single bolus depresses adrenocortical activity for several hours
- Midazolam/Etomidate inductions
  - Midazolam 0.2-0.4 mg/kg IV
  - Etomidate 0.5-2 mg/kg IV to effect

Alfaxalone

- Steroid induction agent
- Cardiovascular stability
- Can cause respiratory depression similar to propofol
- Can be administered IM (cats) for sedation
- Not yet released in US

Maintenance of Anesthesia

- Inhalant Anesthetics
  - Duration of action is not dependent on metabolism
  - Anesthetic depth can be adjusted rapidly
  - Patients benefit from intubation, oxygen supplementation, and ventilatory support
  - Side effects
    - Dose dependent hypotension
    - Loss of cerebral and renal autoregulation
    - Hypothermia
Maintenance of Anesthesia

- Balanced anesthetic techniques
  - Inhalant/injectable combinations
    - Fentanyl CRI
      - High dose 0.3-0.7 µg/kg/min
      - Low dose 2-10 µg/kg/hr
    - Lidocaine
      - 1.2 mg/kg/hr
      - 50 µg/kg/min
    - Midazolam
      - 0.1 mg/kg/hr
      - 0.35 µg/kg/min
    - Ketamine
      - 0.5-1 mg/kg/hr
      - 10-50 µg/kg/hr

Local Anesthetics

- Can be used to target specific areas
- Reduce the need for systemic drugs
- Reduce the MAC of inhaled anesthetics

Local Anesthetic Techniques

- Topical anesthesia
- Infiltration anesthesia
  - Subcutaneous, intramuscular, subpleural, ring block
- Perineural anesthesia
  - Targeting specific nerves
- Spinal anesthesia
  - Epidural, subarachnoid
Local Anesthetics

Epidural Anesthesia

• Can be used for anesthesia of:
  • Pelvis, hind limb
  • Abdomen
  • Thoracic surgery
  • Thoracic limb

Intraoperative Monitoring

• Minimal monitoring should include ECG, indirect blood pressure and temperature

• Ideal monitoring for critical patients should include:
  • ECG
  • Direct blood pressure
  • Pulse oximeter
  • End-tidal gas measurements
  • Blood gas analysis
  • Additional monitoring
  • Urine output
  • Central venous pressure
Potential Intraoperative Problems

- Cardiac rhythm disturbances
  - Marked changes in HR may indicate other clinical problems
  - Tachycardia
    - Inadequate anesthesia, inadequate blood volume, poor tissue perfusion, hypercapnia, hypoxia
    - Prevents adequate ventricular filling, increased myocardial work and oxygen demand

Potential Intraoperative Problems

- Cardiac rhythm disturbances
  - Ventricular Premature Contractions (VPC’s)
    - Most common arrhythmia
    - Indicates area of myocardial irritation
    - pH < 7.20, hypothermia
  - When to treat:
    - Multiform morphology
    - Increasing frequency or runs
  - Therapeutics
    - Lidocaine (first drug of choice)
      - Dogs: 2 mg/kg IV bolus
      - Cats: 0.5 mg/kg IV bolus
    - Procainamide
      - 1-4 mg/kg IV
    - Esmolol
      - 0.2-0.5 mg/kg IV

Potential Intraoperative Problems

- Hypotension
  - Most commonly due to inadequate preoperative fluid replacement or failure to keep up with intraoperative losses
  - Low diastolic pressures (<40 mm Hg), positional changes in blood pressure, damping of BP during positive pressure ventilation indicate need for more volume
  - Myocardial depression and vasodilation may be due to anesthetic agents
    - Decrease inhalant (balanced techniques)
Potential Intraoperative Problems

- Pharmacologic support may be needed for hypotension
  - Dopamine
    - 2-10 μg/kg/min
    - Increased heart rate, contractility, and vascular tone
  - Ephedrine
    - 0.1-0.25 mg/kg
    - Increased heart rate, contractility, and vascular tone
    - Causes release of endogenous epinephrine
  - Calcium chloride
    - 0.1 mg/kg slowly over 5-15 minutes
    - Increases contractility, cardiac output, and vascular tone
  - Vasopressin
    - 0.05-0.1 units/kg
    - Increases vascular tone and decreases heart rate

Potential Intraoperative Problems

- Hypoventilation
  - Accurate assessment requires measurement of carbon dioxide
    - Arterial blood gas
    - End-tidal gas analysis
      - Generally runs 5-10 mm Hg lower than ABG
    - Significant respiratory acidosis and myocardial dysfunction can result
  - Causes:
    - Depressed respiratory center
    - Anesthetic drugs, increased ICP
    - Limited chest wall or diaphragm movement
    - Disrupted neuronal interface with respiratory muscles

Potential Intraoperative Problems

- Hypoventilation
  - Treatment
    - Address underlying cause
    - Positive-pressure ventilation
      - Ventilator settings
        - Tidal volume 10-15 ml/kg
        - Breaths/min 8-15
        - Caution in animals with pulmonary injury (contusions)
        - Excessive pressures can result in further barotrauma
        - Keep PIP < 12 cm H₂O
Potential Intraoperative Problems

- Hypoxemia
  - \( \text{PaO}_2 < 60 \text{ mm Hg} \) (\( \text{SPO}_2 < 90\% \)) oxygen delivery becomes severely compromised
  - Causes:
    - Hypoventilation
    - Rare in patients receiving supplemental oxygen
    - Diffusion impairment
    - Rare unless entire lung tissue is compromised or low inspired concentration of oxygen
    - Ventilation-perfusion mismatching
    - Most common cause in patients with pulmonary disease
    - Ventilation of under-perfused lung
    - Blood flow to under-ventilated lung
  - Treatment
    - Positive pressure ventilation
    - PEEP (5-10 cm H\(_2\)O)

Postoperative Care

- Supportive
  - Continued fluid therapy
  - Antibiotics as necessary
  - Continued monitoring of vital parameters
  - Analgesia ± sedation

Postoperative Analgesia

- Pain has negative effects
  - Delay recovery
  - Reduce eating and drinking
  - Decrease pulmonary function
  - Increase oxygen consumption
  - Delay tissue healing
  - Increase catecholamine release
  - Cause immobility and insomnia
Postoperative Analgesia

- **Opioids**
  - Mainstay of acute pain relief
  - Hydromorphone, morphine, methadone
  - Fentanyl CRI or Patch
- **Lidocaine**
  - Analgesic, antiarrhythmic, reduces reperfusion injury, free radical scavenger
- **Ketamine**
  - Strong analgesic for somatic pain
- **NSAIDs**
  - Controversial use in critical patients
  - Single post-operative dose in well hydrated patient?

Take Home Message

- Trauma patients present a unique challenge
- Internal injuries may not be readily apparent
  - Should be expected
  - Biochemical response may be delayed
  - Provide analgesia
  - Select drugs with favorable cardiovascular profile
  - Monitor

Questions?